

CLAIMS

1. Method of operating a four-stroke internal combustion engine including a variable volume combustion chamber defined by a piston reciprocating within a cylinder between top-dead center and bottom-dead center points and an intake valve and an exhaust valve controlled during
5 repetitive, sequential exhaust, intake, compression and expansion strokes of said piston comprising:
 - providing an exhaust event during which the exhaust valve is open for expelling combusted gases from the combustion chamber;
 - subsequent to the exhaust event, providing a period of
10 simultaneous closure of the exhaust and intake valves during at least a portion of the intake stroke of the piston effective to establish a sub-atmospheric pressure condition within the combustion chamber; and,
 - providing an intake event during which the intake valve is open for ingesting fresh air into the combustion chamber.
2. Method of operating a four-stroke internal combustion engine as claimed in claim 1 wherein said sub-atmospheric pressure condition within the combustion chamber reaches at least about 42 kPa sub-atmospheric.
3. Method of operating a four-stroke internal combustion engine as claimed in claim 1 wherein said sub-atmospheric pressure condition within the combustion chamber terminates not earlier than about 75 degrees past exhaust stroke top dead center.
4. Method of operating a four-stroke internal combustion engine as claimed in claim 1 wherein said sub-atmospheric pressure condition within the combustion chamber reaches at least about 42 kPa sub-atmospheric and

terminates not earlier than about 75 degrees past exhaust stroke top dead
5 center.

5. Method of operating a four-stroke internal combustion engine
as claimed in claim 1 further comprising providing a rebreathe event wherein
said exhaust valve is open during at least a portion of the intake event.

6. Method of operating a four-stroke internal combustion engine
as claimed in claim 5 wherein said rebreathe event is initiated subsequent to
initiation of said intake event.

7. Method of operating a four-stroke internal combustion engine
as claimed in claim 6 wherein said rebreathe event is terminated prior to
termination of said intake event.

8. Method of operating a four-stroke internal combustion engine
as claimed in claim 5 wherein said rebreathe event is characterized by lift of
said exhaust valve no greater than about 50% of maximum valve lift.

9. Method of operating a four-stroke internal combustion engine
as claimed in claim 5 wherein said rebreathe event is initiated about 10 to
about 30 degrees subsequent to initiation of said intake event.

10. Method of operating a four-stroke internal combustion engine
as claimed in claim 9 wherein said intake event is initiated about 20 to about
60 degrees after exhaust stroke top dead center.

11. Method of operating a four-stroke internal combustion engine
as claimed in claim 5 wherein said rebreathe event is terminated prior to
termination of said intake event.

12. Method of operating a four-stroke internal combustion engine as claimed in claim 11 wherein said rebreathe event is terminated about 10 to about 40 degrees prior to termination of said intake event.

13. Method of operating a four-stroke internal combustion engine as claimed in claim 12 wherein said intake event terminates about 20 to about 60 degrees after intake stroke bottom dead center.

14. Method of operating a four-stroke internal combustion engine as claimed in claim 5 wherein said intake event is initiated about 20 to about 60 degrees after exhaust stroke top dead center and is terminated about 20 to about 60 degrees after intake stroke bottom dead center, and said rebreathe event is initiated about 10 to about 30 degrees subsequent to initiation of said intake event and is terminated about 10 to about 40 degrees prior to the termination of said intake event.

15. Method of operating a four-stroke internal combustion engine including a variable volume combustion chamber defined by a piston reciprocating within a cylinder between top-dead center and bottom-dead center points and an intake valve and an exhaust valve controlled during repetitive, sequential exhaust, intake, compression and expansion strokes of said piston comprising:

establishing a low pressure event within the combustion chamber during the intake stroke of the piston; and,

establishing a combustion chamber rebreathe event during the intake stroke of the piston by controlling a rebreathe event exhaust valve opening and closing wherein the rebreathe event exhaust valve opening occurs during the low pressure event.

16. Method of operating a four-stroke internal combustion engine as claimed in claim 15 wherein said low pressure event is established by controlling phasing of an exhaust event exhaust valve closure and the intake valve opening.

17. Method of operating a four-stroke internal combustion engine as claimed in claim 16 wherein the exhaust event exhaust valve closure absolute phase relative to exhaust stroke top dead center is not greater than the intake valve opening phase after exhaust stroke top dead center.

18. Method of operating a four-stroke internal combustion engine as claimed in claim 17 wherein the exhaust event exhaust valve closure occurs before exhaust stroke top dead center.

19. Method of operating a four-stroke internal combustion engine as claimed in claim 17 wherein the exhaust event exhaust valve closure occurs after exhaust stroke top dead center.

20. Method of operating a four-stroke internal combustion engine as claimed in claim 19 wherein the intake valve opening occurs about 0 to about 60 after the exhaust valve closure.

21. Method of operating a four-stroke internal combustion engine as claimed in claim 20 wherein the exhaust event exhaust valve closure occurs about 0 to about 20 degrees after exhaust stroke top dead center.

22. Method of operating a four-stroke internal combustion engine as claimed in claim 16 wherein the exhaust event exhaust valve closure occurs about 20 degrees before exhaust stroke top dead center to about 20 degrees after exhaust stroke top dead center.

23. Method of operating a four-stroke internal combustion engine as claimed in claim 16 wherein the rebreathe event exhaust valve opening occurs about 10 to about 30 degrees after the intake valve opening.

24. Method of operating a four-stroke internal combustion engine as claimed in claim 16 wherein the intake valve opening occurs about 20 degrees after exhaust stroke top dead center to about 60 degrees after exhaust stroke top dead center.

25. Method of operating a four-stroke internal combustion engine as claimed in claim 16 wherein exhaust event exhaust valve closure occurs about 20 degrees before exhaust stroke top dead center to about 20 degrees after exhaust stroke top dead center and the intake valve opening occurs
5 about 20 degrees after exhaust stroke top dead center to about 60 degrees after exhaust stroke top dead center.

26. Method of operating a four-stroke internal combustion engine as claimed in claim 25 wherein exhaust event exhaust valve closure occurs about exhaust stroke top dead center to about 20 degrees after exhaust stroke top dead center.

27. Method of operating a four-stroke internal combustion engine as claimed in claim 24 wherein the rebreathe event exhaust valve opening occurs about 10 to about 30 degrees after the intake valve opening.

28. Method of operating a four-stroke internal combustion engine as claimed in claim 16 wherein exhaust event exhaust valve closure occurs about 20 degrees before exhaust stroke top dead center to about 20 degrees after exhaust stroke top dead center, the intake valve opening occurs about
5 20 degrees after exhaust stroke top dead center to about 60 degrees after

exhaust stroke top dead center, and the rebreathe event exhaust valve opening occurs about 10 to about 30 degrees after the intake valve opening.

29. Method of operating a four-stroke internal combustion engine as claimed in claim 16 wherein exhaust event exhaust valve closure occurs about exhaust stroke top dead center to about 20 degrees after exhaust stroke top dead center, the intake valve opening occurs about 20 degrees after
- 5 exhaust stroke top dead center to about 60 degrees after exhaust stroke top dead center, and the rebreathe event exhaust valve opening occurs about 10 to about 30 degrees after the intake valve opening.

30. Method of operating a four-stroke internal combustion engine including a variable volume combustion chamber defined by a piston reciprocating within a cylinder between top-dead center and bottom-dead center points and at least one intake valve and one exhaust valve controlled
- 5 during repetitive, sequential exhaust, intake, compression and expansion strokes of said piston comprising:
- providing a closed exhaust valve and a closed intake valve during an expansion stroke of said piston;
 - providing an open exhaust valve and a closed intake valve during
 - 10 an exhaust stroke of said piston;
 - providing a closed exhaust valve and a closed intake valve during an intake stroke of said piston to establish a low pressure condition within the combustion chamber;
 - providing an open exhaust valve and an open intake valve during
 - 15 said intake stroke of said piston to ingest combusted gases and fresh air, respectively, into said combustion chamber; and,
 - providing a closed exhaust valve and a closed intake valve during a compression stroke of said piston.

31. Method of operating a four-stroke internal combustion engine as claimed in claim 30 wherein closure of the exhaust valve that is open during the exhaust stroke occurs at an absolute phase angle relative to exhaust stroke top dead center about not greater than the phase angle after
5 exhaust stroke top dead center at which opening of the intake valve occurs.

32. Method of operating a four-stroke internal combustion engine as claimed in claim 31 wherein the closure of the exhaust valve that is open during the exhaust stroke occurs about 20 degrees before exhaust stroke top dead center to about 20 degrees after exhaust stroke top dead center.

33. Method of operating a four-stroke internal combustion engine as claimed in claim 30 wherein the opening of the intake valve occurs about 20 degrees after exhaust stroke top dead center to about 60 degrees after exhaust stroke top dead center.

34. Method of operating a four-stroke internal combustion engine as claimed in claim 31 wherein the closure of the exhaust valve that is open during the exhaust stroke occurs about exhaust stroke top dead center to about 20 degrees after exhaust stroke top dead center.

35. Method of operating a four-stroke internal combustion engine as claimed in claim 34 wherein the opening of the intake valve occurs about 20 degrees after exhaust stroke top dead center to about 60 degrees after exhaust stroke top dead center.

36. Method of operating a four-stroke internal combustion engine as claimed in claim 35 wherein opening of the exhaust valve that is open during said intake stroke of said piston occurs about 10 to about 30 degrees after the intake valve opening.